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AXKT PHASE 3 FINAL REPORT

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CDRL A013

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This document fulfills the requirements that are specified by CDRL item A0013, contract N00014-88-C-6027. Specifically, results of three reliability tests (Phase III) for the Sippican Air launched Expendable K Meter buoy (AXKT) are summarized and analyzed. This data was derived from notes that were sent to Sippican from NORDA (Appendix A) as well as various correspondence through the life of the project.

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Scope: This document fulfills the requirements that are specified by CDRL item A0013, contract N00014-88-C-6027. Specifically, results of three reliability tests (Phase III) for the Sippican Air launched Expendable K Meter buoy (AXKT) are summarized and analyzed. This data was derived from notes that were sent to Sippican from NORDA (Appendix A) as well as various correspondence through the life of the project.

Program Summary: Three separate tests were conducted during the period of 1990 through 1992 in which a total of 60 AXKTs were deployed for purposes of gathering operational reliability of this developmental device. The three tests were done in differing environments to characterize the AXKT buoy over a range of conditions. In each of the tests, the buoys were deployed from a plane and the resulting data was received via RF link by the deploying plane as well as a nearby surface ship that acted as a ground truth by employing a cable lowered reference instrument (MER) in which AXKT data would be later compared against.

After each test in which 20 units were deployed, the data would be analyzed for proper buoy operation, quality of data an accuracy of data with relation to the MER. This data set would then be used to indicate changes that should be made to the AXKT system in order to improve the overall quality and reliability of the buoy. If a particular change was deemed necessary, the change was implemented prior to the following test, and the following test was then analyzed to determine if the change was successful or not.

Program Summary: For each of the tests, twenty two (22) AXKTs were built substantially in conformance with Sippican drawing 305609. Changes may have been done to the buoys if previous tests (applicable to tests 2 and 3) indicated that deficiencies exist. The transmission channels that the buoys were tuned to were roughly equally distributed between channels 12, 14 and 16, allowing for simultaneous drops of three buoys per deployment.

From each lot, one or two units were 'deployed' in non-air launched configuration in a tank as a test sample for uncovering gross latent problems with the particular build. Buoy activation, probe release, signal transmission and buoy scuttling were verified to be within nominal limits. The remaining units were then shipped to the final destination in preparation for actual deployment via aircraft at sea.

For each of the tests, the buoys were deployed by a P12 aircraft capable of receiving the AXKT signals. The resulting signal was recorded on an analog tape for later reduction. In most cases, three buoys were deployed simultaneously for each of the available channels. In addition to the aircraft, a surface ship acted as a secondary recording station as well as providing ground truth data from a non-expendable, cable lowered optical profiler (MER).

Test Results:

The following discusses each of the tests and describes problems encountered and resolutions to the problems. The analysis of these tests are a result of data reduction of the data set primarily by NORDA and of hardware analysis (where available) by Sippican.

Test 1

This test took place off the coast of Norway on September of 1990. Twenty buoys were deployed with varying results. The problems are broken down according to subsystem, i.e., probe, transmitter, receiver and are summarized according to failure mode. The source data that this analysis is derived from can be found in appendix A.

For each of the several failure modes that were experienced during the test, a description of the problem, along with a possible cause is given.

In characterizing the AXKT system, it is important to point out that some of the modes may or may not be considered probe/buoy failures in that at least one of the problems was due to poor reception of the RF signal by the deploying aircraft. This problem manifested itself by the acquisition of the signal by the support ship but not by the aircraft. As a result of this, the test summary contains rankings for calling the reception problems as failures as well as allowing these units to 'pass'.

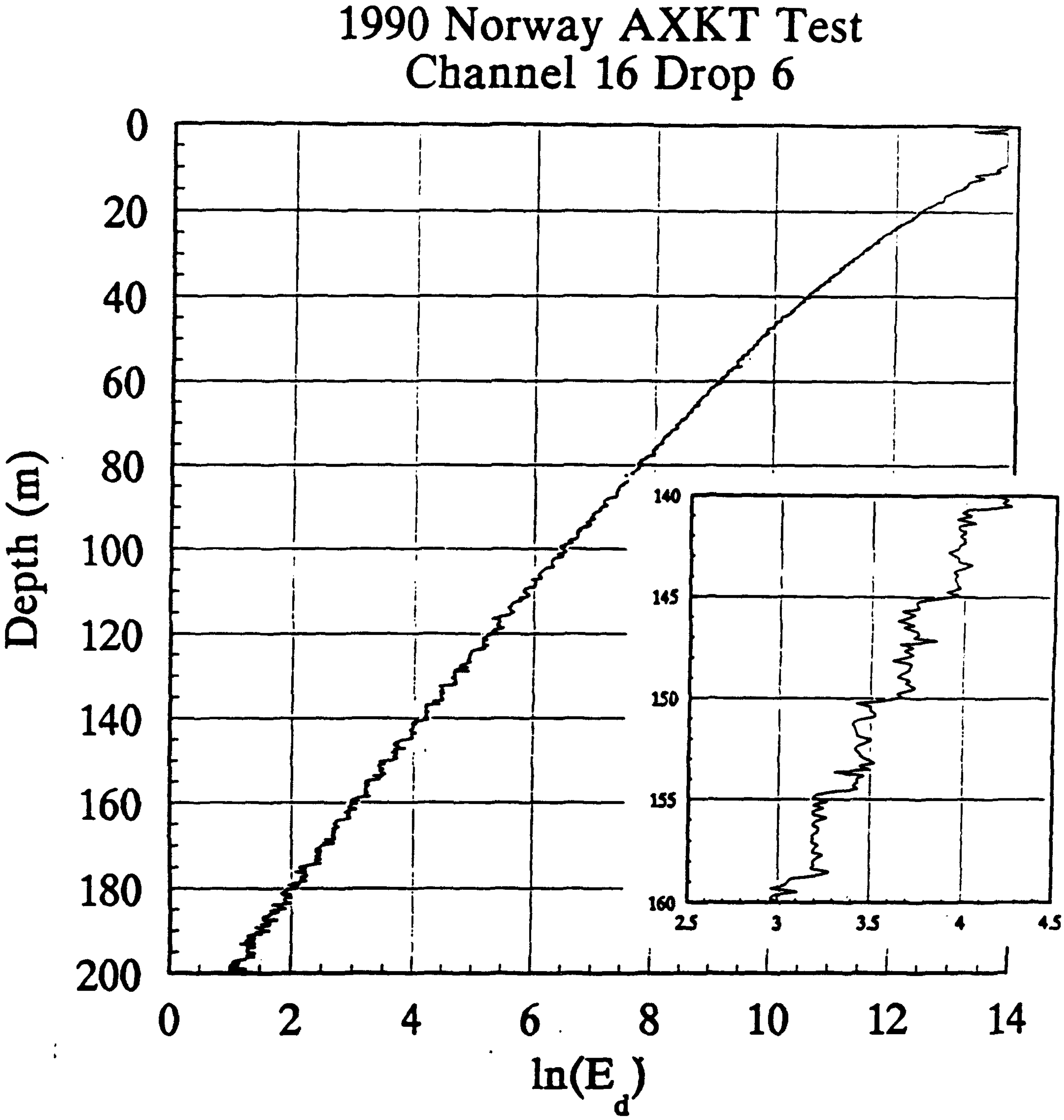
Problem 1 - Total Loss of Data

Three probes during the test were deployed without any data being received by either the plane or the support ship. This type of problem is the hardest to diagnose as a complete loss of data could reflect a number of problems. Previous testing has indicated several potential reasons for this type of failure; a) lack of buoyancy due to improper bag inflation, b) damage to the RF transmitter, c) damage to the BT wire link from the probe to the surface unit. Analysis of the analog recordings could identify problem c as the transmitter would still activate and cause a carrier to be present. The presence of the carrier would indicate that the buoy is functional and would therefor point to the probe as a source of trouble.

Lack of buoyancy could be caused by a problem with the CO_2 inflation mechanism or the sea water battery that activates the CO_2 system. In either case, the unit would not surface after deployment, resulting in total loss of data. Damage to the RF transmitter or antenna system could have occurred during shipping or on water impact during deployment. The remaining systems would still be operational but with out the ability to transmit data, the end result is the same.

Problem 2 - Spikes in the Data of the Aircraft and/or Support Ship
Large scale spikes exhibited themselves on eleven of the units dropped. In the majority of cases (8 units) the spikes only appeared on either the aircraft or the ship but not on both. This is evidence that the problem stems from improper RF communication to the ship or plane and not from the unit itself per se. A ninth probe exhibited the same type of problem but extended to both the ship *and* the aircraft. Subsequent playback of the audio tape resulted in a satisfactory data set. The spikes are very evident and are different from the 'noise' that appears on a number of units. Where the noise is a result of the acquisition process and the measurements of the probe, the spikes are a result of no data for a brief period of time that result in the plotting process to create a solid line across the plotting screen. The obviousness of these spikes allows editing of the data set without loss of accuracy in the remaining points.

Problem 3 - Steps in the Data
On data from three of the units, there appeared a granularity or quantization in the profile. This staircase phenomenon appears when certain conditions are meet, i.e., the optical intensity is at a particular level (usually at a low illumination level) and the rate of attenuation with depth is relatively slow. When these conditions are met, the data will not correctly follow the illumination gradient smoothly, but will 'lock' onto a particular illumination level for a short length of time and then snap to a new light level and remain at this new level. This process repeats itself many times, thereby creating a trace the appears to have steps in what would normally be a smoothly changing illumination level. Graph 1 illustrates this effect. In the inset of the graph is an expanded view of the steps. As can be seen, these steps increase in severity as the light intensity decreases. The effect of these steps is to introduce a large amount of noise in the computed K value. In the extreme, the K is zero for a short depth where the step plateau is and the K is huge for the place where the step begins its transition. Currently the only way to deal with the steps to filter the raw irradiance data and then calculate the K value from this data.


1990 Norway AXKT Test
Channel 16 Drop 6
Depth (m)
0
20
40
60
80
100
120
140
160
180
200
0
2
4
6
8
10
12
14
ln(E_d)
140
145
150
155
160
2.5
3
3.5
4
4.5

Graph 1

Problem 4 - Spikes in Both Aircraft and Surface Ship

One unit exhibited spikes on both the deploying aircraft and surface ship. It is assumed that the location and amplitude of the spikes in the data is the same regardless of the source of the data set. In this case, this noise probably stems from the buoy itself. There are several possibilities for these noise spikes, with the actual cause remaining unknown. If a surface wave passed over the buoy and caused a momentary immersion of the antenna, there will be a brief dropout of RF signal. Other likely candidates are: 1)pinholes in the BT wire that links the probe to the surface buoy. As these conductors are current carrying members, small pinholes will quickly begin to corrode and will appear to present a varying impedance to the drivers in the probe. This will cause the amplitude of the received signal to vary which will be subsequently transmitted to the data processing equipment, showing up as deviations in the data. 2) RF spikes from another transmitter that is operating in the area, 3) Faulty RF transmitter in the buoy that is intermittent and causing losses in the data set.

Problem 5 - Surface Saturation

Several of the XKT units exhibited signal saturation at the surface just after probe release. This condition (See graph 1) causes an apparent constant level of optical illumination (a 'K' of zero) for a certain depth. This condition is almost certainly a result of mis-scaling the electronics in either the probe or the buoy as the actual detector as considerable greater dynamic range that the electronics. There is no processing technique that will re-create this piece of data, it is completely lost. After a certain depth is reached, the water column will have attenuated the light to the point where the signal becomes 'on-scale' and will be processed. As the measurement for K is a differential measurement, the loss of this data does not effect the remaining data.

Failure Summary

The following summarizes the failures/deficiencies that were encounter during this test. Statistics are listed for the type of problem, the number of units that were affected and the percentage that this represents.

Problem	# Units	% Tota	Cum
No data	3	15%	15%
Spikes in Plane and Ship	1	5	20
Spikes in Plane or Ship	9	45	65
Steps in data	3	15	80
Good Probes	4	20	100

Note: Some unspecified number of units had surface saturation, number not known.

Test 2

The second test took place at Juan De Fuca, December of 1990. Eighteen buoys were deployed with varying results.

Changes Made:

Due to the short interval between test 1 and test 2, no remedial action was taken to address some of the problems that were encountered during the first test. As a result, many of the observations from the first test are again noted here.

Old Problems

Four of the units experienced the same problem of having noise in the aircraft or the surface ship, but not both. For the most part, the ship received good data and the aircraft experienced a large amount of spiking and data breakup. As the ship received a good signal, it is unlikely that the AXKT system itself had problems. The more likely cause is a marginal RF link between the buoy's transmitter and the receiver. More data will be necessary before a definitive answer can be obtained.

Another problem that was repeated in this test was the presence of 'steps' in the data. In this case, it was isolated to a single unit, although it is likely that the environmental and test conditions had more to do with the reduction of occurrence than any actual change in the buoy.

New Problem 1 - Poor Profile

One of the units during this test exhibited a clean signal, but showed a irradiance profile that deviated from the nominal profile that the remaining units displayed. A comment in the test notes questioned whether the effect was due to a passing cloud. It is unknown as to the actual cause of this deviation.

New Problem 2 - Lack of Optical Data
One of the units, the probe and buoy transmitted a correct temperature profile but lacked any optical data. The presence of the optical signal indicated that the BT wire, the buoy and the transmitter were functional and the problem lie in the probe itself. The optical detector and conditioning electronics are separate from the temperature measuring components and a failure within any one of these optical modules would cause such a failure type.

New Problem 3 - Failure to Scuttle within Allotted Time
This problem, although noted as new was also observed during the first test but observations were uncertain. It appears that virtually 100% of the units failed to scuttle within the twelve minute period that is allocated for this function. The units would cease transmitting after approximately six minutes as intended, but instead of releasing the buoyancy bag as they should have, resumed transmitting an RF carrier. This caused a problem when deploying multiple probes as in this test, as each probe would occupy its respective RF channel for an extended period of time, preventing additional probes from being launched.

New Problem 4 - Surface Saturation of Optical Signal
Several units that were deployed exhibited a condition of 'saturation' when the probe was still near the surface. Upon descending to a deeper depth, the units would then resume normal operation and provide a good data set (See graph 1).

The symptoms of this problem suggest that the problem lies in the electrical scaling of the probe's conditioning electronics and not due to the optics themselves. The electronics are scaled so as to nominally accept the brightest possible conditions (overhead sun, low latitudes) while still providing good low light level data. Due to normal manufacturing tolerances, this scale moves around to some degree. If the scale is not positioned so that these tolerances are taken care of, this limiting problem could arise. In this case the solution is to either tighten the manufacturing tolerances or to rescale the nominal values to accommodate these variations.

Failure Summary

The following summarizes the failures/deficiencies that were encounter during this test. Statistics are listed for the type of problem, the number of units that were affected and the percentage that this represents.

Problem	# Units	% Tota	Cum
No data	1	5.5%	5.5%
Spikes in Plane and Ship	3	16.5	22
Spikes in Plane or Ship	4	22.0	44
Steps in data	1	5.5	50
Poor Profile	1	5.5	55.5
No Optical Data	1	5.5	61
Surface Saturation	3*	16	**
Good Probes	7	39.0	100
Total	18		

* This number is an estimate, the true number is unknown

** The cumulate error is not available as the actual probes that this problem occurred on is not known and probably overlaps other errors to some degree.

Test 3

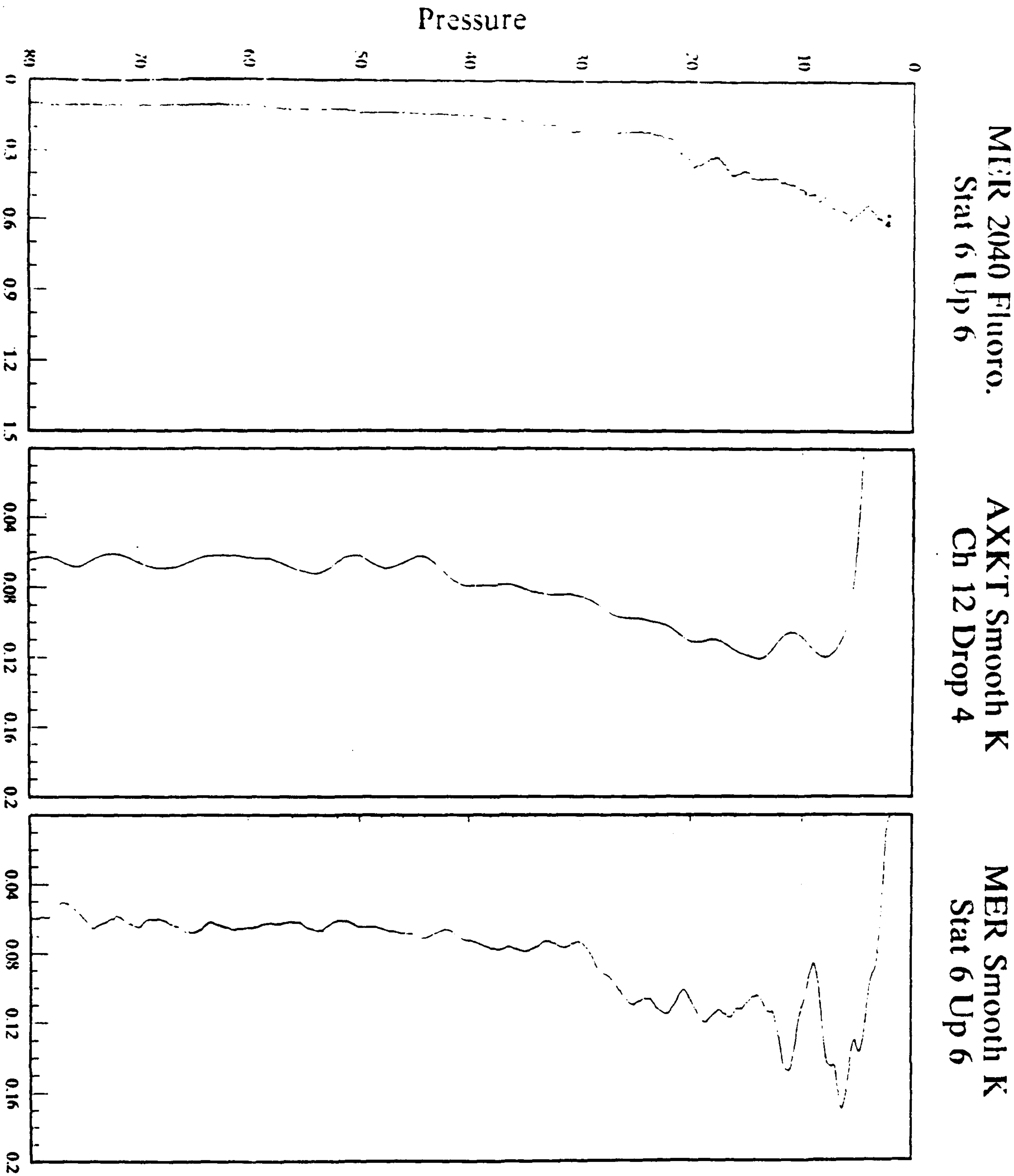
The third test took place in the north Pacific, September of 1992. Eighteen buoys were deployed, again with varying results. In this test, several changes were implemented to address some of the issues that were raised by the first two tests.

Changes Made

During subsequent and deeper analysis of the data from the first two tests, it appeared that in addition to the problems noted above, the system had a problem with being overly slow in responding to changes of illumination (See graphs 2 and 3). This slow response time manifested itself by 'smearing' optical features in the water column, making them appear to be much smaller in amplitude and much longer in duration. This problem becomes even more apparent when the K calculation is performed on the data. Another artifact that this slow response created was at very near surface, the probe was slow to respond to the sudden change in illumination that was experienced when the probe left the relative darkness of the launch tube and into the daylight. As can be seen in graph 2, the MER's data, even though it was started only at 5 meters or so, the XKT's data does not begin until approximately 8 meters. During this start up period, the apparent illumination is increasing, giving the appearance of a negative 'K' for the first ten meters.

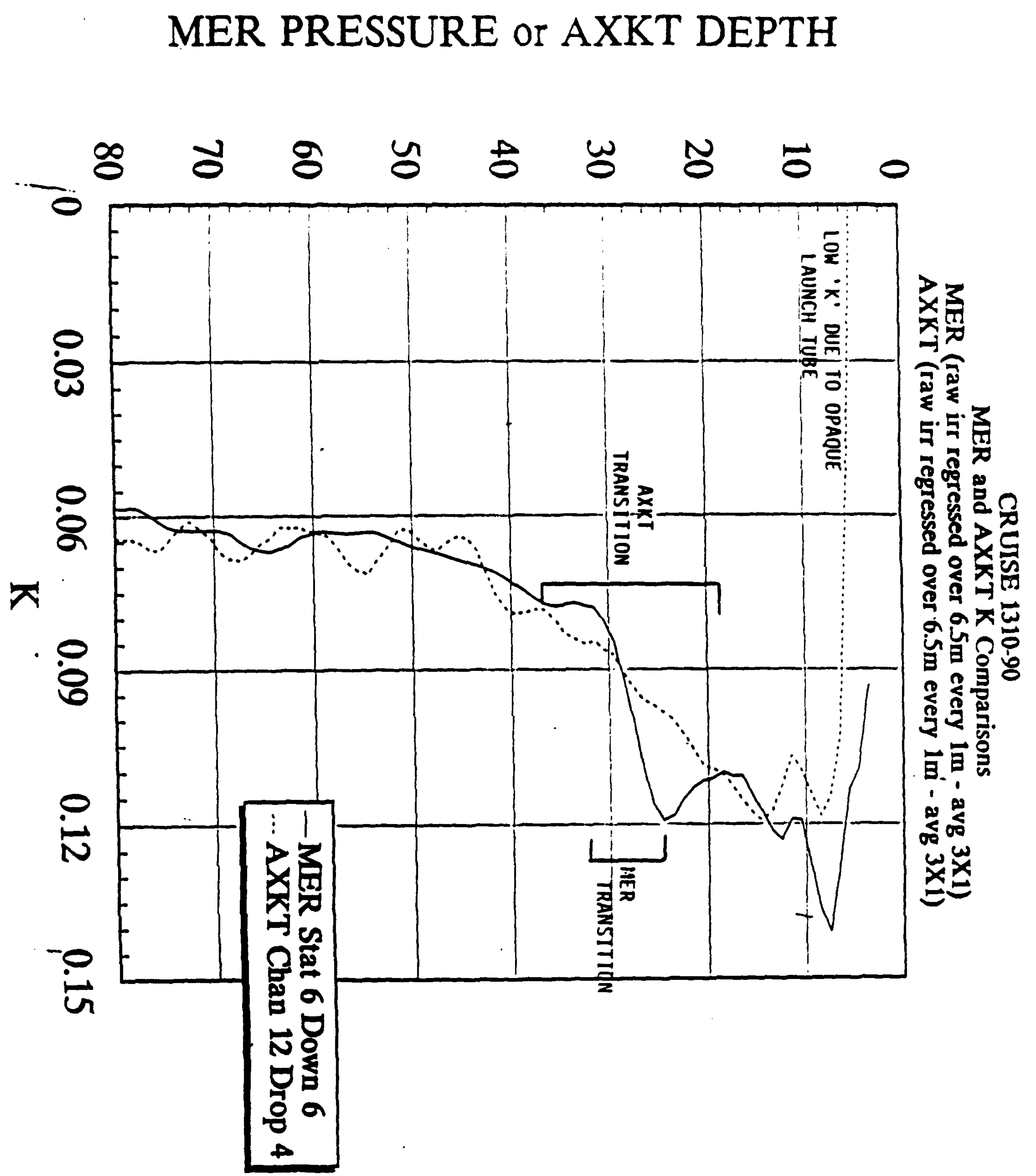
In order to address this problem, several changes to made to the system. Electrical changes were made to the conditioning electronics in the probe, particularly in the logging amplifier, to speed up the response time of the probe. These changes resulted in a speed increase of approximately 2 to 1. Another change to address the near surface problem was the adoption of semi clear launch tubes that would allow the probe to see a much brighter environment during the stabilization period that occurs just prior to probe release.

To address the scuttling problem that existed for every probe, analysis showed that a previous test configuration that prevented the unit from scuttling in a short period of time was never removed from the production units. This electronic 'trap' was intended to allow buoy retrieval after deployment for subsequent fault diagnosis during



Pressure
MER 2040 Fluoro.
Stat 6 Up 6
AXKT Smooth K
Ch 12 Drop 4
MER Smooth K
Stat 6 Up 6

Graph 2


MER PRESSURE or AXKT DEPTH
CRUISE 1310-90
MER and AXKT K Comparisons
MER (raw irr regressed over 6.5m every 1m - avg 3X1)
AXKT (raw irr regressed over 6.5m every 1m - avg 3X1)
LOW 'K' DUE TO OPAQUE LAUNCH TUBE
AXKT TRANSITION
MER TRANSITION
K
0
10
20
30
40
50
60
70
80
0
0.03
0.06
0.09
0.12
0.15
MER Stat 6 Down 6
AXKT Chan 12 Drop 4

Graph 3

development. The change for test three was to remove this trap and allow the unit to scuttle normally.

The 'steps' that were observed during the first two tests were verified in the laboratory with a controlled light source (Discussed later in this report). It appears that the probe electronics, particularly at the low light levels, would create an inadvertent feedback path that would lock the signal at a particular level. This level would remain until the outside illumination changed sufficiently to force the circuitry to 'step' to another level. At this point the correction to this problem is unknown. More laboratory analysis must be done to ascertain the exact conditions under which this problem appears.

The problems are broken down as in the first test. Except for new problems or exceptions, the failure analysis is not repeated here.

Old Problems

Probably the most notable problem during this test was the continued presence of the scuttling problem. During the test, the units were observed to continue to radiate after a period of time after the commencement of supposedly end of transmission. Several of the buoy units from the test were recovered and shipped back to Sippican. The recovered hardware allowed much more complete diagnostics to be performed as compared to theoretical scenario analysis.

It appears that, although the removal of the test mode trap allowed the electronics to initiate the scuttle sequence, under certain environmental conditions, the inflation bag that provides buoyancy for the unit will trap air and not allow the unit to submerge for termination.

The inflation bag is inflated with a squib fired CO_2 cartridge and remains inflated until the time for RF cessation and scuttle occurs. A small heating element is located on the side of the bag which burns through the walls of the bag, releasing the floatation gas at the proper time. This heating element is located at approximately one third up the wall of the overall bag. In normal operation, the element burns a small hole in the bag which releases the gas pressure allows the unit to lose some of its buoyancy. The remaining gas escapes by the action of normal sea surface activity on the face of the bag. As this action usually takes a number of minutes, there exists in the electronics a switch that disables the RF transmitter for this period of time.

In situations where the sea is very calm, the remaining gas will not be messaged out of the bag for a very long time and after the normal

expected scuttle time, the electronics unknowingly cycle around and begin to transmit a carrier again. This process will continue until the unit actual sinks below the surface or the sea battery loses power (a good battery in relatively warm conditions will last for almost an hour). In every unit that was recovered and sent to Sippican, the burn element had indeed burned a small hole in the bag thereby venting the initial gas pressure. The fact that the units remained surfaced for recovery indicates that a sufficient amount of gas remained to provide the needed buoyancy for floatation.

In the future this design will have to be modified for use in such conditions if this type of test is to be repeated (multiple deployments on the same channel, calm surface conditions). Such a modification could either be mechanical (raising the puncture point on the bag), electronic (greatly extending the time that the RF switch remains disabled), or a complete redesign of the scuttling mechanism.

Effects of Changes from Previous Design

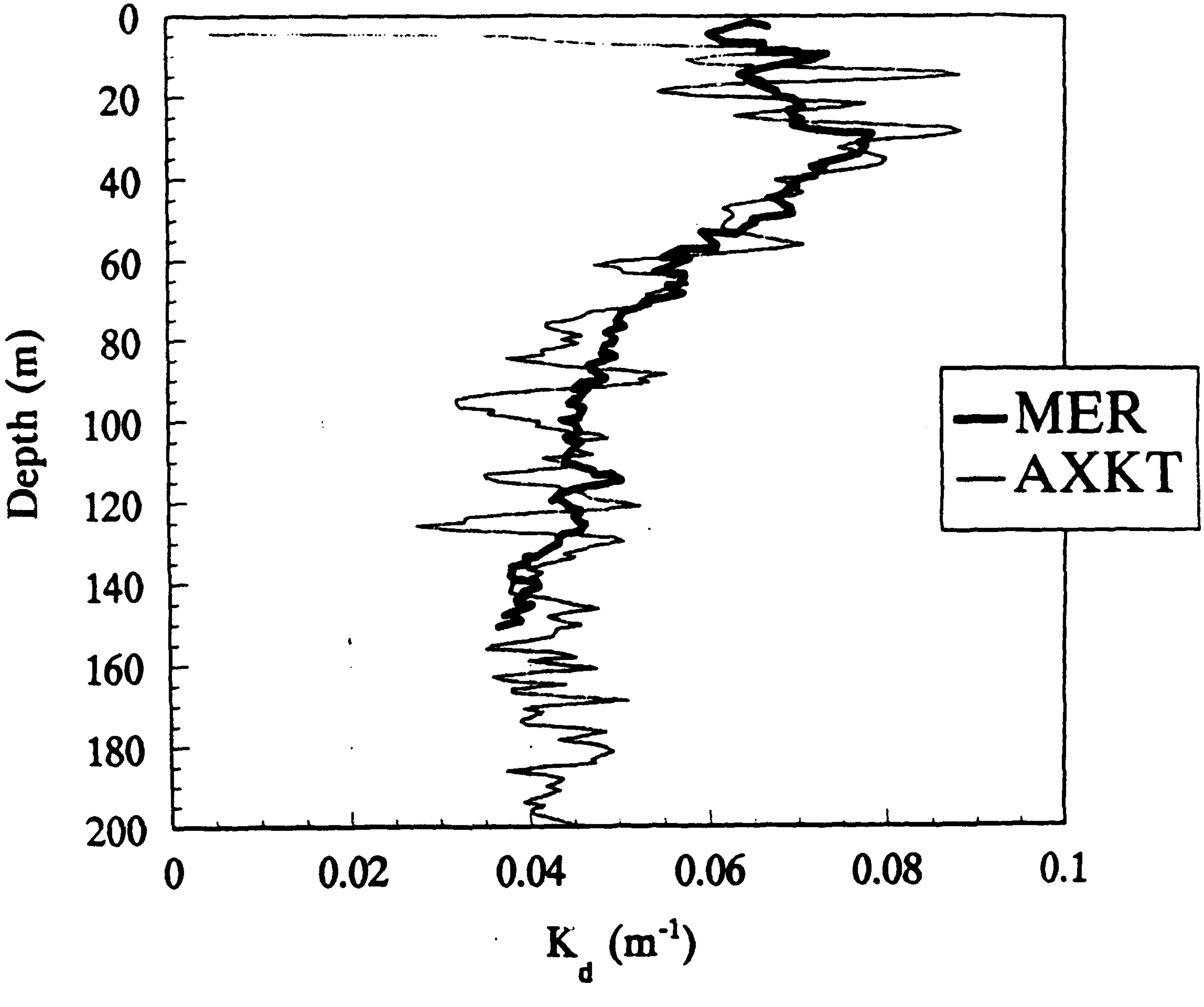
The three major changes that were implemented prior to this test were 1) Altered electronics to decrease the time response of the probe, 2) Using translucent launch tubes to allow the probe to equilibrate prior to launch, 3) Removing the scuttle 'trap' to allow proper scuttling.

Change 3 has already been addressed previously. The disappointing results of this changed caused difficulties in analyzing the other failures in that the overriding RF interference from previously deployed units obscured much of the data from active units.

The effect of the electronic change to speed up the response of the probe looked encouraging. The comparison of data from the cable lowered MER and the few AXKTs that gave a good data set showed that the 'smearing' effect is considerably smaller with both instruments showing the same transition regions. Graph 4 shows a data set from the AXKT as compared to the MER optical data. The region from 20 to 60 meters, which has the greatest dynamics, indicates that the XKT keeps up with the MER for the average trend of data. The greater fluctuations of the XKT are possible due to the relatively rapid drop rate (relative to the MER), necessitating shorter averaging bins that allow for greater noise levels.

The translucent launch tube also showed promise. Again, due to the very few units that performed well, the slow response to the full ambient light level was greatly diminished, presumably due to the combined

1992 Pacific AXKT Test
Channel 12 Drop 6



Graph 4

effects of the increased measuring speed and the ability of the probe to optically equilibrate during the pre-launch stabilization phase.

Failure Summary

Due to the significant number of units that were unusable because of the RF interference effect, and lack of statistical data of actual problems with the deployed probes, it is impossible to analyze the failures on a numerical basis. Suffice to say that the presence of the RF interference/scuttling problem is a severe one when a test of this style is implemented.

Noted Problems that were independent of Sea Tests

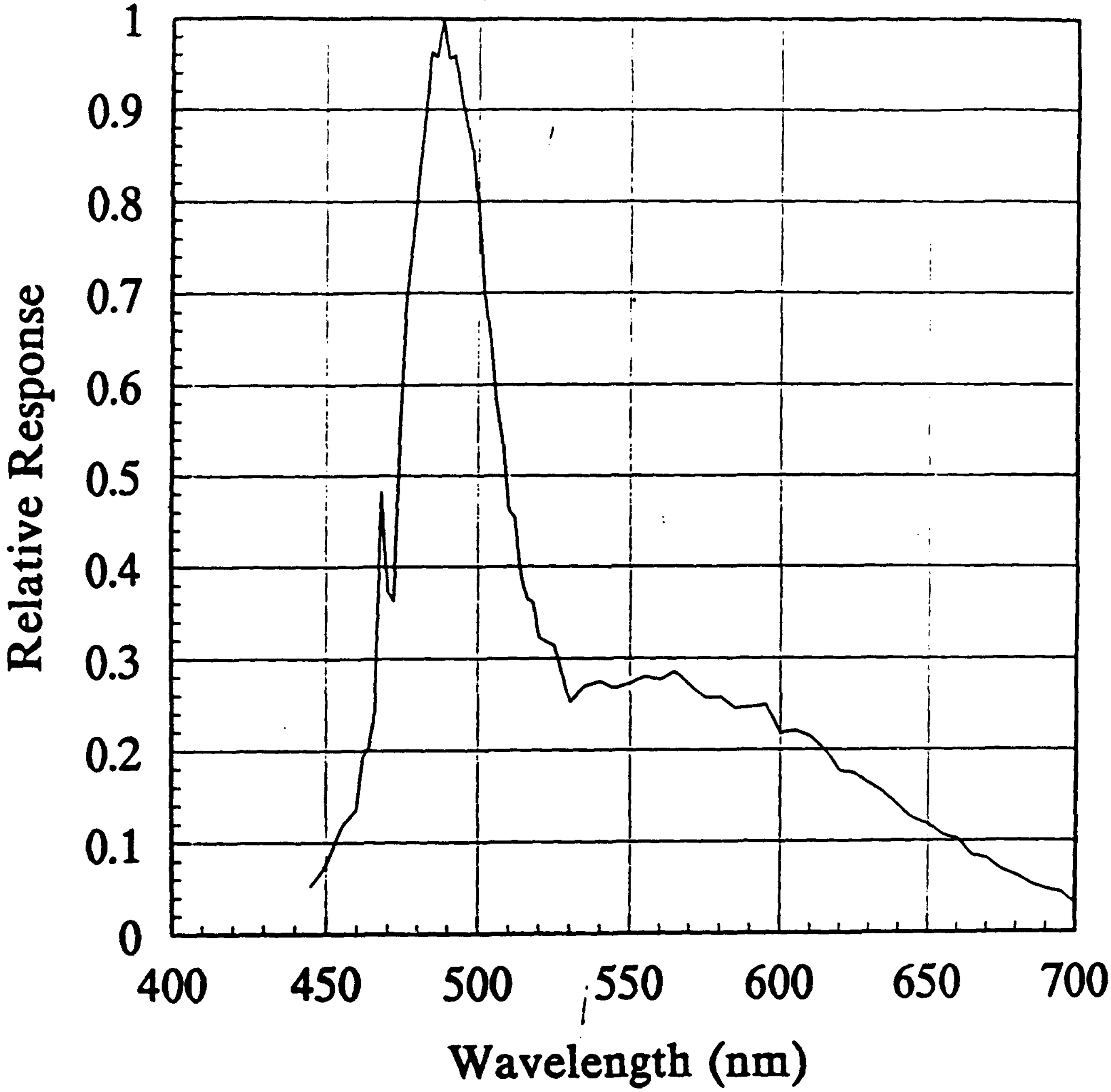
Several problems were noted that were not directly related to the sea tests. During the development program, the two XKT probes were subjected to several optical tests to characterize the system in terms of spectral sensitivity, spatial response, and log conformity. These tests were done by San Diego State University at the Center for Hydro-Optics & Remote Sensing (CHORS) facility.

Spectral Response
The probe was characterized for sensitivity versus wavelength (See graphs 5 and 6). In both cases the pass band appeared to be +/- 20 nanometers (half power point). It was noted that at the longer wavelengths, (>530 nm), the transmission of optical energy remained above 10%. This red energy could introduce some error into the signal at the near surface due to biasing because of selective attenuation of the water column. Some work will be required to identify new filters to reduce this 'red shift'.

Staircase Revisited
During the tests for logarithmic conformity, the digitization or staircase effect was again noted. The manifestation of the effect is shown on graph 7 (Also graph 1 for a real time display). Again, further work will be required to determine the cause and the corrective action of this problem.

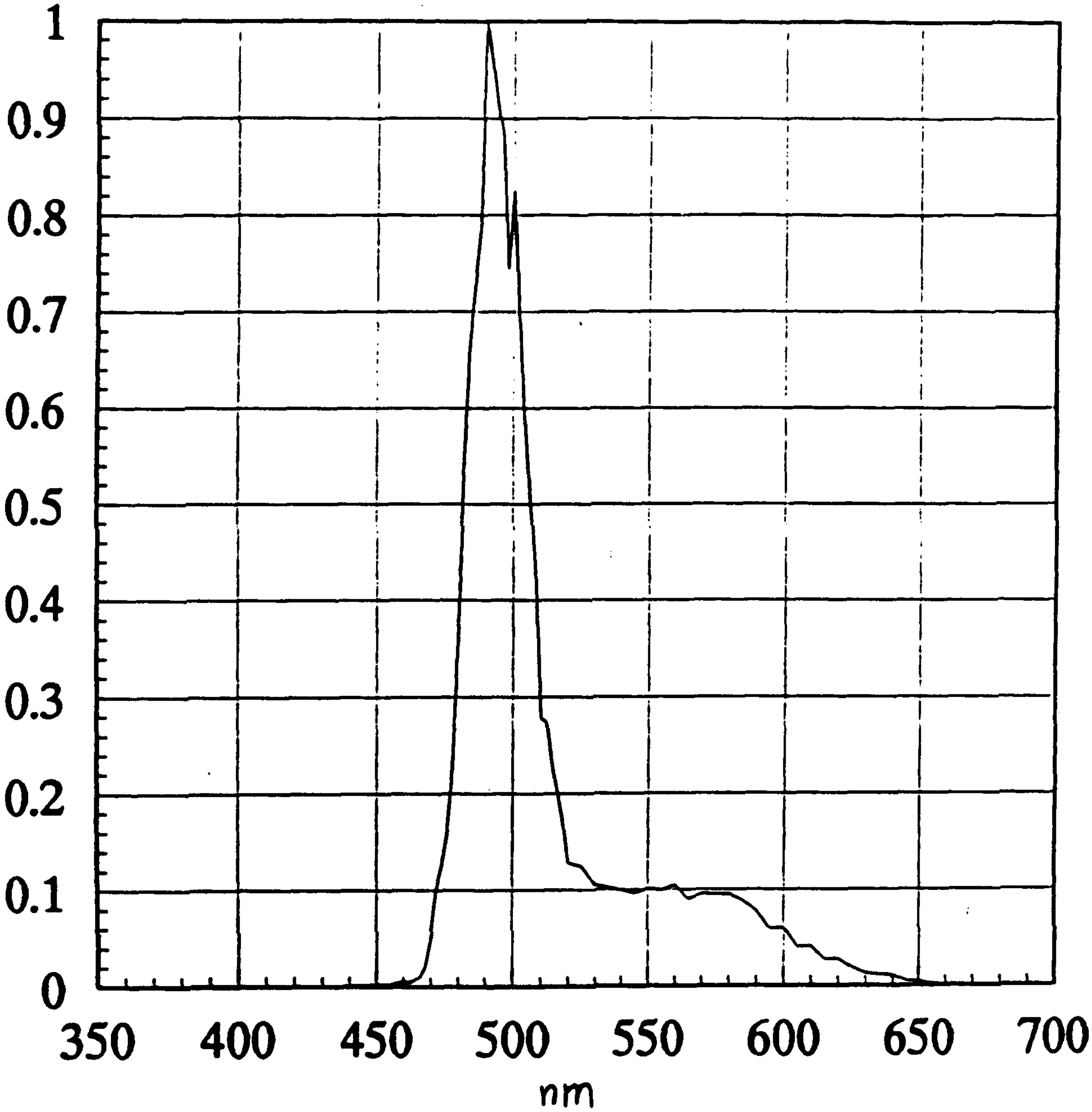
Cosine Response:
The directional response of the XKT detector was measured and compared to the ideal response of cosine weighted device. Graph 8 indicates the actual versus true cosine response of the detector assembly as a function of incident angle. As can be seen, the device has less than 10% error at the low (<30 degrees) angles, increasing with angle until at 45 degrees, the error increases to approximately 25%. It was noted that by recessing the actual detector within the housing, a much better correlation might be expected. It is also possible that reflections off the Delrin diffuser may be skewing the response with different angles. Testing needs to be done to determine the best geometry to produce the desired response.

AXKT #1 Normalized Response Function



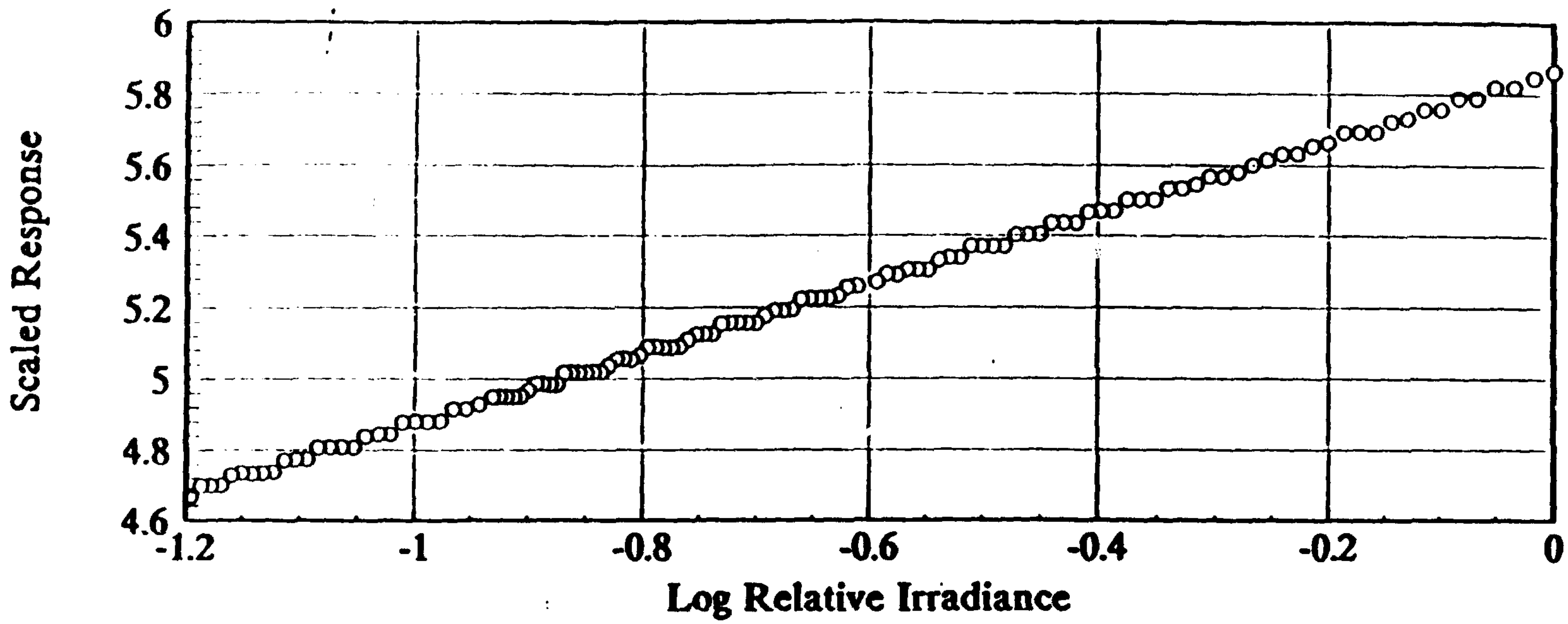
Graph 5

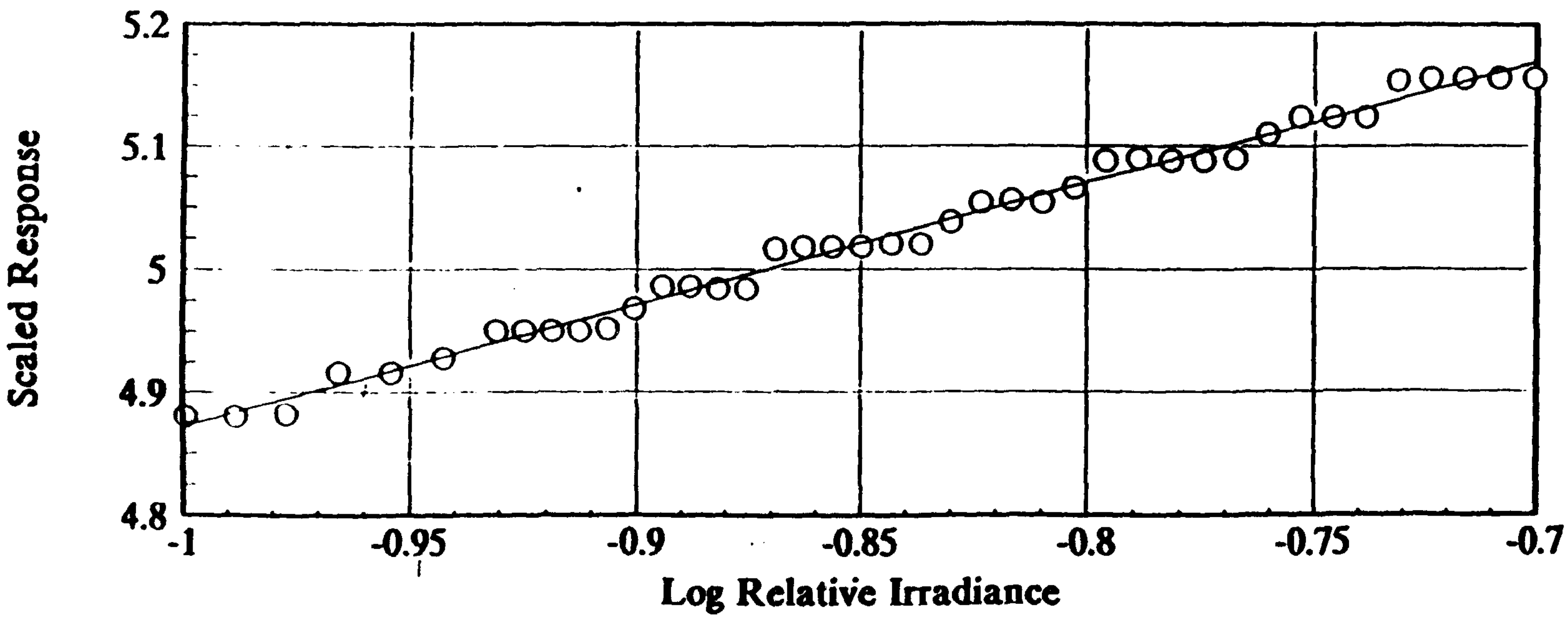
AXKT #2 Normalized Response Function



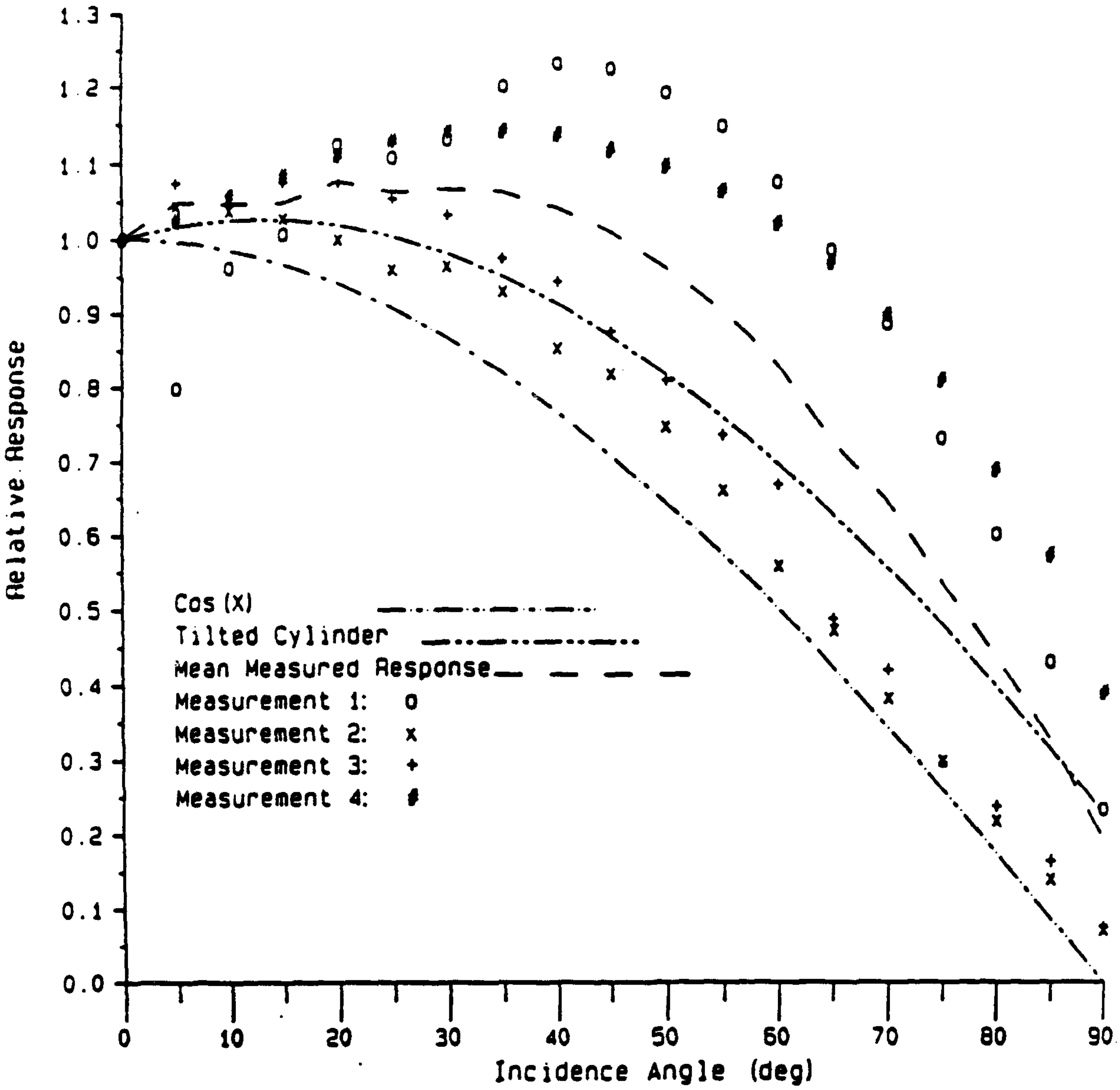
Graph 6

AXKT #2 Staircase Effect





Graph 7



1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Relative Response
0
10
20
30
40
50
60
70
80
90
Incidence Angle (deg)
Cos (X)
Tilted Cylinder
Mean Measured Response
Measurement 1: o
Measurement 2: x
Measurement 3: +
Measurement 4: #

Graph 8

References:

Mueller, J. - Radiometric Characterization of an Airborne Expendable K and Temperature Meter
San Diego State University/CHORS Technical Memorandum 006-93

Report from Weiderman, A. NORDA, currently unpublished regarding overall system performance of the AXKT

Appendix A

The following is a listing of the test notes that were taken during the first two tests. This text was taken from transmittals from NORDA to Sippican 2/28/92.

"AXKT PROFILE SHIP VS AIRCRAFT SIGNAL COMPARISON"

A good trace is one in which exponential decay is obvious and with < 10 spikes in the trace which can be removed by processing techniques.

Vest fjord, Norway 23 September 1990:

Drop	Chan	SN	Comments
1	12	002	Good ship trace, no aircraft recording
1	14	019	Good ship trace, no aircraft recording
1	16	021	No ship, No aircraft: Bad probe
2	12	007	Similar traces; good
2	14	003	Similar traces; good
2	16	001	Similar traces; good
3	12	016	Similar traces; good
3	14	018	Good ship trace, erratic aircraft data
3	16	020	No ship, No aircraft: Bad probe
4	12	006	Good ship trace, 0-20m clipped in aircraft
4	14	010	No ship, Aircraft noise from 90-120m and increasing irradiance with depth/ replay gave good aircraft trace.
4	16	017	Good ship (some spikes), Aircraft good
5	12	009	Ship-breakoff at 175m, interference between 60-80m, Aircraft occasional spike
5	14	004	Good ship trace, No aircraft data
5	16	013	No ship, No aircraft: Bad probe
6	12	008	No ship, Aircraft good trace (steps)
6	14	011	Good ship trace, Aircraft 0-10m clipped, both with steps in profile
6	16	005	Good ship trace, Aircraft 0-10m clipped, both with steps in profile
7	12	AXBT	AXBT Drop
7	14	014	Good ship trace, noisy aircraft data
7	16	012	Ship started late, Aircraft noisy data